respiration gating. These data then underwent reformatting, and segmentation, and dynamic 3DE reconstructions derived. Optimal 3DE studies were obtained in all. Based on the experience in these 36 pts, we were able to define specific 3D projections that yielded more detailed or additional information compared to 2DE. These new 3D cuts-ections allowed us to delineate the relative size and degree of malalignment of the VSD, their spatial orientations and relations, morphology of the infundi-bulum, the internal caliber and continuity with the proximal pulmonary arteries, and pulmonic valve morphology and annular size in a reliable manner. Besides defining these abnormalities, 3DE yielded unique en face views of the VSD, and coronal and cylindrical display of the infundi-bulum and pulmonary arteries, not available in 2DE. In the 8 post-op studies, 3DE depicted the geometry and relative size of the reconstructed outflow tract, and continuity to the pulmonary arteries and the integrity of VSD patches. Overall, 3DE was superior in portraying the functional morphology of lesions associated with TOF both pre- and post-operatively. We conclude that dynamic 3DE, easily performed by the transthoracic approach, provides important spatial information that could be valuable in planning catheter and surgical interventions in TOF.

1002-86 Direct Quantitation of Atrial Septal Defect Size by Volume-Rendered Three-Dimensional Echocardiography: In Vitro Validation Studies

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The ability of volume-rendered three-dimensional echocardiography (3DE) in displaying atrial septal defects (ASD) in a dynamic mode has been demonstrated; however the quantitative accuracy of 3DE in sizing the defect is not known. In this study, we examined the reliability of measuring the ASD size directly on 3-D image reconstructions. In 10 explanted pig hearts, we created a total of 10 ASDs of various types and shapes (2 primum, 5 secundum and 3 sinus venosus). Suspending the hearts in a water bath, 2DE images were collected. An ultrasound transducer was mounted on a motorized parallel scanning device and we attained 21 6 slices over a distance of 60 mm. Digital reformation, interpolation and segmentation (threshold and opacity) were subsequently performed, and 3DE reconstructions accomplished; Appropriate cut planes were used to display the ASDs *en face*. Using a new processing algorithm, measurements of maximum diameter (Max D) and minimum diameter (Min D) were done directly on the 3DE image. These were compared with independently measured anatomic data. In addition, interobsever variability was also assessed. *Results:* All 3D reconstructions successfully displayed the ASDs of all types. The site, shape and size were well appraised in it's true form and corresponded well with the anatomic specimens. The Maximum D was (Mean ± SD in mms): 16.9 ± 5.6 (range 8.5–27.5) by anatomy and 17.5 ± 4.8, (range 9–24) by 3DE; Minimum D was: 12.3 ± 4 (range 6–18) by anatomy, and 12.6 ± 4 (range 7–19) by 3DE. The correlations between 3DE (y) and anatomy (x) were: Maximum D: $y = 0.83x + 3.4$; $r = 0.97$, $p < 0.001$. Min D: $y = 0.92x + 1.3$, $r = 0.92$, $p < 0.001$. Interobserver concordance was also excellent for both Max and Min diameters ($r = 0.93$ and $r = 0.98$). *Conclusion:* 3DE provides excellent visualization of ASDs in unique en face projections not available in conventional imaging techniques. 3DE makes it possible to derive multiple diameter measurements of ASDs not attainable from 2DE. Measurements of ASD, now readily performed directly on 3DE images, accurately define the size of ASDs. These qualitative and quantitative capabilities of 3DE enhance the clinical potential of this technique in sizing the ASDs required for catheter or surgical interventions.

1002-87 The Results of Spontaneous and Clamshell Umbrella Closure of the Fenestrated Fontan

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The fenestrated Fontan (FF) procedure was performed in 24 consecutive patients (pts) — aged 1 to 13 years (mean 5.4) — with one or more high risk factors in order to reduce operative mortality and morbidity. This study evaluated their outcome. The fenestration was 2.7 mm in 4 pts, 4 mm in 12, and 4.5 mm in 8. One pt (4.2%) died in hospital. One pt died 7 months after FF at cardiac transplantation. Survivors have been followed for 16 to 48 months (mean 34). Early O2 saturations (sats) were 88–92% (mean 90) in 2.7 mm and 69–89% (mean 79.4) in larger FF. All four 2.7 mm, one 4 mm and four 4.5 mm fenestrations closed spontaneously but of these one 2.7 mm (at 2 weeks) and one 4 mm (at 3 years) required recreation of a hole by trans-baffle puncture and balloon dilation because of congestive failure. Nine 4 mm and two 4.5 mm fenestrations were closed with a clamshell umbrella (U). Following U closure, RA pressure increased from 12 ± 1.8 to 14.7 ± 2.4 mmHg ($p < 0.01$), O2 sats increased from 80.2 ± 6.6 to 93.7 ± 4.6% ($p < 0.001$), but the artriovenous O2 saturation difference increased from 18.8 ± 4.1 to 25.8 ± 6.7% ($p < 0.02$). Unusual systemic venous collaterals resulted in R to L shunts in 3 pts and recurrent pericardial effusions in 1; all were successfully coil occluded. Atrial baffle leaks resulted in large R to L shunts in 3 pts after effective fenestration closure with U. One was successfully coil occluded; the other 2 have O2 sats of 84 and 88% late post U. Clinical follow-up has shown a high incidence of dysrhythmias (atrial tachycardia in 5, 4 requiring amiodarone; sick sinus syndrome in 3; seven of these required a pacemaker). Three pts have had severe congestive failure, one immediately post U closure. Two pts have protein losing enteropathy. Two pts have had strokes: 1 early and minor; the other 4 months after U closure and major. Eighteen of 22 survivors are in NYHA Class 1.

Conclusions: The fenestrated Fontan resulted in a low operative and intermediate mortality. Most fenestrations either closed spontaneously or were closed with a clamshell umbrella. Although most patients have a good functional result, dysrhythmias and other late complications are frequent.

1002-88 Is Angiocardiography Necessary in the Preoperative Assessment of Uncomplicated Ventricular Septal Defect in Infancy?

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With current 2-dimensional echocardiography (ECHO) and colour-flow Doppler it may no longer be necessary to perform preoperative angiocardiography (ANGIO) for patients with a primary diagnosis of uncomplicated unrestrictive ventricular septal defect (VSD). We compared the sensitivity and specificity of both techniques in the detection of additional VSD's and commonly associated lesions using as "gold standard" a combination of surgical findings plus postoperative ECHO's. A total of 130 consecutive patients undergoing VSD repair in infancy between January 1991 and March 1994 were studied. The mean age at repair was 0.48 ± 0.26 year and mean weight at repair was 5.0 ± 1.5 kg. All ECHO's were performed prior to ANGIO. Associated lesions included right ventricular muscle bundles (RVMB), sub-aortic stenosis (sub-AS), and persistent ductus arteriosus (PDA). No case of aortic valve prolapse causing aortic incompetence was identified, and aortic arch abnormalities were generally surgically addressed prior to ANGIO.

The sensitivity and specificity of the two techniques in the detection of additional VSD's were:

	Sensitivity	Specificity
Echo	63%	99%
Angio	63%	95%

Out of a total of 8 cases with additional VSD's, 2 were small anterior muscular defects which were clinically insignificant, and only seen by colour-flow Doppler.

The results for detection of associated lesions were:

	Sensitivity		Specificity	
	Echo	Angio	Echo	Angio
RVMB	73%	73%	93%	96%
Sub-AS	63%	38%	96%	97%
PDA	80%	80%	98%	99%

Our results suggest that ECHO is comparable to ANGIO in the preoperative assessment of uncomplicated VSD in infancy. Therefore, ANGIO should no longer be necessary in the evaluation of these patients.

1002-89 Cost Effectiveness of Coil Embolization of Patent Ductus Arteriosus

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Transcatheter closure of patent ductus arteriosus (PDA) using the Rashkind occluder is less effective and more costly than surgical closure. Coil embolization is an alternative method of closing a small PDA. We reviewed our experience to compare current costs of coil embolization and surgical closure. Between 3/3/86 and 8/31/94, 19 patients (ages 16 months to 43 years) underwent cardiac catheterization for possible coil embolization of PDA. Fourteen (74%) had successful coil placement (range of minimum PDA diameter 1.0–3.0 mm; fluoroscopy time 27 ± 10 min). Closure was documented by Doppler echocardiography in 13 patients; one patient with a trace shunt has not had post-catheterization follow-up. Five PDA's were not embolized and had subsequent surgical ligation. Two were not attempted because of deficient aortic diverticulum and 3 failed (2 with minimum PDA diameter ≥3.3 mm had snare retrieval of coils embolized into the pulmonary artery and 1 was removed due to poor coil position). One of the patients who failed PDA embolization required surgical femoral artery embolectomy. The last nine patients catheterized (12/1/93–8/31/94) were all successfully embolized without complication.